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NAVAL POSTGRADUATE SCHOOL

Monterey, California



ANNUAL SUMMARY REPORT

RANGE STUDIES PROGRAM

Prepared by O. B. Wilson, Jr.

August 1975

Report for the Period July 1974 - June 1975

Approved For Public Release; Distribution Unlimited

Prepared For: Research and Engineering Department
Naval Torpedo Station
Keyport, Washington 98345

NAVAL POSTGRADUATE SCHOOL
Monterey, California

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This summarizes the activity during FY 1975 of a group of faculty and students in their study and analysis of the long-term requirements and plans for the Naval Torpedo Station, Keyport, Washington, in the area of underwater weapons test-range capability.		

Summary Annual Report

RANGE STUDIES PROGRAM

NAVAL POSTGRADUATE SCHOOL
Monterey, California

In support of the

LONG RANGE DEVELOPMENT PROGRAM

of the

NAVAL TORPEDO STATION
Keyport, Washington

For the period July 1974 - June 1975

August 1975

Approved for public release - Distribution Unlimited.

I. INTRODUCTION

In June of 1973 the Naval Torpedo Station, Keyport, Washington and the Naval Postgraduate School, Monterey, California entered into an agreement to participate in programs of mutual interest and benefit to both establishments. In essence, faculty and their students would engage in the attack on selected, appropriate problems of concern and interest to the Station and consistent with the goals and program of the School. The effort would be in cooperation with the staff of the Station and could involve the temporary exchange of personnel.

Initially a group of faculty from several disciplines was formed. As a first project, the group undertook the examination of the long term requirements of the Station with regard to test range capability with an objective of proposing programs for range improvement. This project is outlined in proposals submitted for Fiscal Years 1974 and 1975 which have been funded by the Station to the amount of \$100,000 for FY-74 and \$137,000 for FY-75. Due to limitations on the availability of faculty members and students, the full expenditures of FY 1974 and FY 1975 could not be performed on the Range Studies Program. As a result some significant amounts of funds were carried over into FY 1975 and into FY 1976.

The faculty participating in this program during FY-75 and their departments were:

Asst. Professor ROBERT S. ANDREWS	Oceanography
Asst. Professor M. H. BANK	Aeronautics
Assoc. Professor A. B. COPPENS	Physics and Chemistry
Assoc. Professor M. L. COTTON	Electrical Engineering
Professor W. P. CUNNINGHAM	Physics and Chemistry
Asst. Professor H. A. DAHL	Physics and Chemistry
Professor David B. HOISINGTON	Electrical Engineering
Professor C. E. MENNEKEN	Electrical Engineering
Asst. Professor V. M. POWERS	Electrical Engineering and Computer Science
Assoc. Professor George L. SACKMAN	Electrical Engineering
Assoc. Professor J. V. SANDERS	Physics and Chemistry
Assoc. Professor D. A. STENTZ	Electrical Engineering
Assoc. Professor J. J. VON SCHWIND	Oceanography
Asst. Professor A. R. WASHBURN	Operations Research and Administrative Sciences
Assoc. Professor J. B. WICKHAM	Oceanography
Assoc. Professor C. O. WILDE	Mathematics
Professor O. B. WILSON	Physics and Chemistry

In view of the magnitude of the project, its long term character, and the relative unfamiliarity of the faculty group with the specific aspects of the problem, a significant fraction of the first year was devoted to a program of indoctrination of the participants in order that they could become familiar with the structure and operation of the Keyport and other Navy underwater

ranges. Although this has continued as new faculty members and students have joined the group, in FY 1975, work was directed towards more specific objectives. As part of this, the group members were organized into small, task-oriented sections:

1. Range Requirements,
2. Signal Coding,
3. Transducers,
4. Ray Tracing,
5. Range Concepts,
6. Non-Acoustic Sensors,
7. Data Transmission, Processing and Display.

The following sections summarize task group activities.

II. Summary of activities

1. Range Requirements Task Group

Faculty: Bank, Cunningham, Stentz, Wilde

Students: LCDR Ronald Baker, LCDR Harold A. Bunch, LT Christy L. Farris,
LCDR Richard J. Staley, LT Arch E. Taylor.

The long-range goals were:

(1) To develop a range requirements list for the current and future weapons systems tested on the Dabob and Nanoose ranges, and (2) to act as an educational liaison among the various subgroups.

During the year much information pertaining to current torpedo design, testing, operation, and maintenance has been received. This is now available for use by members of the Range Studies Group, students of the ASW Curriculum, and students doing thesis work in related subjects.

In working toward meeting the first goal, much of the data collected so far needs to be collated into a more easily retrievable and task oriented order. In order to codify these data it appears that the work on the larger problem must be divided into several smaller efforts. The first will be a study and determination of range requirements pertaining to current torpedo weapon systems, principally the Mk 46 and 48 systems. This study will get under way during the first quarter of FY 76, and will be followed by a study of WSAT exercises which have involved these weapon systems. The sum of these two studies should give a clearer picture of range requirements associated with these weapons, the user's requirements, and should assist in determining what new tests or WSAT programs would be useful in the proofing, testing, and evaluation of these systems. These studies would include weapon systems that make use of these torpedoes, such as the Mine Mk 60. A strong effort is being made to involve students in the WSAT study. It is felt that the experience many of the students have had would be of great value to such a study. The documentation so far collected and mentioned above will be necessary for these studies.

The liaison and education functions have involved several visits to other stations and activities for the purpose of finding documentation and becoming acquainted with weapon systems, problems, and with people actively engaged in weapons system development and testing:

Professor Bank - Visited the Torpedo School Library at San Diego, the Technical and Tactical Libraries at Fleet ASW Center, San Diego, and the Air Combat Maneuvering Range at NAS Miramar.

Professors Hoisington and Stentz visited the Tactics Office at NAS Moffett Field for the purpose of learning more about the operation and effectiveness of the MAD system.

Professors Wilson, Hoisington, Stentz, Bank, and Wilde with others visited NTS, Keyport for the purpose of acquainting students with acoustic ranges, and problems associated with acoustic ranges and associated weapon system testing. During this last visit, contact with NTS personnel interested a number of NPS students in specific problem areas as thesis topics:

- a. LT Staley - Surface Ship Countermeasures Against an Acoustic, Wire-guided Torpedo with Characteristics Similar to those of the Mk 48 Weapon.
- b. LCDR Bunch - Mk 48 Torpedo Self-Noise Problem.
- c. LCDR Baker and LT Farris - Portable Acoustic Range Requirements.
- d. LT Taylor - Investigate the feasibility of using an on-board navigation system in the torpedo exercise head.

Preliminary statements concerning proposed work on these thesis topics have been provided by separate correspondence.

Other activities have involved the offering of the special topics seminar course, EE-4900, for the five students named above. A major part of the student effort was to do background reading on weapons tests related to potential thesis problems and discussing these with their instructors. It seems clear that as a result of this the students have a much enhanced awareness of the acoustic range problems, its operations and its needs. Several commented that they wished they'd had this appreciation and understanding of the functions of the range when they were users in torpedo range tests and WSAT exercises.

2. Signal Coding Task Group

Faculty: Hoisington, Myers, Powers, Sackman
Students: CAPT R. H. Schmidt, USMC

This section of the report summarizes work done during the past year relating to the transmission of coded pulses for tracking of vehicles such as the Mk 46 and Mk 48 torpedoes, on the ranges. At the present time a 1.3 msec unmodulated pulse is used at a carrier frequency of 75 KHz. Increasing the length of this pulse and modulating it offers several potential advantages: (a) increase in detection range for a given peak pulse power due to processing gain; (b) positive identification of each vehicle when two or more are on the range simultaneously; (c) increased precision of vehicle location due to improved measurement accuracy of pulse arrival time; and (d) the capability of adding telemetry information, such as vehicle depth, to the signal.

The Naval Torpedo Station has been developing a phase-reversal modulation system of pulse coding. The development has proceeded in orderly fashion from propagation tests to implementation of a complete system. This appears to be an optimum system in several respects as discussed in a later section. Until an operational system is demonstrated in the field the feasibility of the technique for this application cannot be assured. Therefore NPS has been investigating alternate modulation types and detection methods, and the results to date of these investigations are reported on herein.

The rate at which bits can be transmitted in a coded pulse is limited by the bandwidth of the resonant clock transducer. A method for increasing the permissible bit rate with phase-reversal modulation by combining amplitude and phase modulation has been investigated and is reported on here.

Another problem in any coded pulse system is to find codes with good autocorrelation properties. An investigation by a thesis student of optimum codes for phase-reversal modulation is also reported.

Phase Modulated Coded Signal Development

For binary data transmission, phase modulation becomes phase-shift keying with typical shifts of $\pm \pi/2$ radians (phase reversal modulation). When the modulating code is a symmetrical infinite sequence such as 1010..., the carrier is missing in the resulting spectrum. The sidebands decrease in amplitude with increasing separation from the carrier. Only odd-order sidebands are present.

An optimum method of detecting a phase-reversal-modulated signal is to multiply the received signal by a locally generated carrier which is maintained in phase with the suppressed carrier of the transmitted signal. Unfortunately on the range the frequency of the received carrier is only known to within plus or minus two percent since Doppler-shift can change the carrier frequency by that amount. A Doppler-shift of plus or minus three percent may be encountered in the future when still faster, more highly maneuverable vehicles may be tested.

The method employed by NTS to compensate for the Doppler shift is to employ a phase-locked loop at the receiver to generate a carrier in phase with the suppressed carrier of the received waveform. The square of the received signal is formed using an analog voltage multiplier. This generates the second harmonic of the suppressed carrier, and the phase-locked loop is locked to this second harmonic.

The transmitted signal contains a precursor which is the unmodulated carrier. The precursor is presently six bits long. This is followed by 19 bits of coded pulse and 23 bits of telemetry. The loop acquires phase lock during the unmodulated precursor. The loop bandwidth is wide at this time to insure rapid lock and to allow for Doppler shift of the carrier frequency. The loop bandwidth is then narrowed to insure that during the modulated portion of the pulse the phase-locked loop will remain locked on the second harmonic of the carrier and not shift to some other frequency component. The loop output frequency is then divided by two to obtain the local carrier used to demodulate the received waveform.

The success of this program cannot be assured until a working system is successfully demonstrated in the field. Sources of uncertainty are the large Doppler shift and effects due to the increased attenuation of sound in water with increasing frequency. This latter effect causes distortion of the received signal, the most important aspect of which is frequency modulation of the received signal. In a working paper by Hoisington (1) it is shown that during a sequence of alternate ones and zeros this effect can result in the reduction by one cycle of the number of cycles in the output of the square law device per bit resulting in a significant reduction in the average frequency of the signal.

In tests carried out at Dabob Bay on 16 and 17 June, 1975, it was shown that the major problems are well on their way to solution. The phase-locked loop did remain synchronized with pulses with simulated Doppler shifts of plus and minus two percent. Some problems remain to be solved. During these tests, for example, the telemetry signal was often incorrectly decoded, particularly when there was a Doppler shift. The NTS appears to be well on the way to solving these remaining problems, however.

Alternate Detection Methods

Since there was initially uncertainty about the ultimate success of the phase-locked-loop development, NPS personnel investigated the feasibility of certain alternate approaches: (a) differential detection with adaptive delay to match the Doppler shift as measured during a signal precursor; (b) transmission of a pilot carrier at a frequency displaced from the frequency of the suppressed carrier, and derivation of the carrier at the receiver from the pilot carrier by frequency synthesis; and (c) the use of amplitude modulation rather than phase modulation. The first and third of these approaches appear to have greatest promise. Myers notes that AM, being a noncoherent system, is less affected by Doppler shift, and an unmodulated precursor might not be necessary (2). A disadvantage of a noncoherent system is the need for a larger signal-to-noise ratio or longer code for a given bit error rate. Myers has made experimental comparisons of AM and PRM signals as transmitted from one pop-out type clock transducer through water in the NPS sonar tank to a second pop-out transducer.

Hoisington has carried out a preliminary investigation of a system in which a pilot carrier is transmitted, and used to generate a local carrier at the receiver (1). It appears that such a scheme would be feasible. Approximately 4 dB of additional power would, however, be required from the transmitter for a given signal-to-noise ratio. Implementation of this method would probably be more complex than the method being pursued by Lindstrom, and would require a great deal of development.

Use of Stepped AM to Reduce Transducer Response Time

At 75 kHz, a transducer with a $Q = 5$ reaches steady state in about 5 cycles of the carrier signal. At the data rates considered, this rise time may be a significant part of a bit interval. It is desirable in some instances to reduce this rise time. Such reduction can be realized by initially overdriving the transducer for a fraction of the duration of a bit. The transducer was simulated electrically. The results of some testing show that the rise time can be reduced to 2 cycles with about a 45% initial increase in applied voltage during these first 2 cycles of the 75 kHz carrier. Photographs and other comments are included in the paper by Myers (2).

Code Selection

Captain R. H. Schmidt, USMC completed a thesis under the direction of V. M. Powers in which the coding theory aspects of choosing suitable code sequences for target identification and for telemetry are investigated (3). Much of the thesis consists of a summary of previously published work on the theory of algebraic coding; major references are listed. Aspects of the application of this theoretical base to real-time underwater tracking of Mk48, Mk46 or other vehicles are considered. The codes may be developed for real-time reconstruction, vehicle identification for closely spaced vehicles, and potentially for internal data and command transmission to or from the range computer site during a run. This could help in solving the acoustic command link (ACC) problems in the Mine Mk60, Mobile Target Mk30 and possibly in the control of submarines (i.e. to use ACC instead of UQC for data transfer). Bounds on the number of code words available for given code lengths are established, and a procedure for selecting suitable codes is suggested. This would be an improvement over previous exhausting-search approaches where all possible combinations were attempted. Copies of Captain Schmidt's thesis have been previously forwarded to the Naval Torpedo Station. Further development of this work seems warranted.

Reports

- (1) David B. Hoisington, "Transmission of Subcarrier on Clock Oscillator Signal". (Working Paper - Internally Distributed) July 1975.
- (2) Glen A. Myers, "Quarterly Report on Naval Torpedo Station Research (Coding Group)", July 1975. (Internally Distributed)
- (3) M.S. Thesis: An Investigation of Binary Codes for Underwater Tracking Systems by R. H. Schmidt (Naval Postgraduate School, September 1974, Advisor: Powers).

3. Transducers Task Group

Faculty: Wilson, Stentz, Sackman
Students: CDR R. Johnson, LCDR A. H. P. Shaw

A. The Problem

The impetus for the work in this area came from problems associated with the "clock" transducer, which is used to generate the acoustic pulses for the basic ranging process at NTS Keyport. The problems are: limited life, unsatisfactory beam patterns at oblique angles of transmission and non-uniformity in the phase and frequency response, and coupling of acoustic energy into the torpedo body and its subsequent reradiation into the water, a problem with the quiet mobile target. This task relates closely to the coded pulses program as part of an integrated range study.

B. Summary of Activities

It is believed that a different configuration of radiating surfaces may be a fruitful approach. Accordingly, several different configurations have been considered and radiation patterns calculated using a computer model based

on the theory described by Laird and Cohen ("Directionality Patterns for Acoustic Radiation from a Source on a Rigid Cylinder", Journal of the Acoustical Society of America, Vol. 24, p. 46, 1952). The model permits a plotting of the radiation pattern for two kinds of rectangular sound sources and for a circular (annular) piston radiator, mounted on the surface of a rigid cylindrical baffle of infinite length. The pattern produced by this program for the uniformly driven rectangular arc source is identical to that derived by others for the same dimensions.

The computations are complex and require a great deal of computer time. For this reason and because of time limitations on CDR Johnson's stay at NPS, only a limited number of input values were tried. That is, a transducer design has not been achieved. However, the computer model should be usable for design work.

As a follow-on thesis activity, another officer-student, LCDR Shaw, has begun calculations of radiation patterns and the design of elements for experimental tests. Partly because of the large amount of computer time required for the cylindrical baffle model, Shaw's design work is based on calculations using a plane baffle. This permits a relatively short turn around time on trial runs. Some components have been ordered in order to construct an experimental transducer. Mechanical units for mounting experimental transducers in a test tank and for conducting beam pattern measurements have been designed and are being constructed. Some of the hardware has been provided by NTS for the tests.

Publications:

M.S. Thesis: Models for Computing the Directional Radiation of Sound from Sources on a Rigid Cylindrical Baffle by R. R. Johnson (December 1974; advisor: Wilson).

4. Ray-tracing Task Group

Faculty: Coppens, Dahl, Sanders, Wickham
Students: LT Bankston, LT Karon

An experiment was conducted on the range at Dabob Bay to test the accuracy of the acoustic range determinations. These data have direct impact on both the cost of range operations and torpedo data accuracy. It is believed that the costs of performing daily sound velocity measurements may be affected by a categorization-error analysis. In addition, all proof torpedoes require accurate depth and range coordinate comparison, e.g. in TIES for the Torpedo Mk48.

The results of the data analysis are:

- (1) Autotape data have been plotted and curves fitted and the analysis completed. Periodic variations were observed but the full reasons are not understood.
- (2) Output range coordinates X, Y from NTS computer program NUTRAK have been plotted and compared with smoothed Autotape curves for these coordinates.
- (3) Range Z-coordinate has been plotted and compared with known depths.

The data showed that the computed depth was too great for all measured stations. This has been studied and is now understood.

A computer analysis of effects of using different sound velocity profiles in vehicle-tracking programs has been made with the following summary of results:

(1) Preliminary work in the thesis of LT Karon:

a. Two measurement stations analyzed.

b. Assumption of layered isogradient water gave better results with fewer layers needed.

(2) Continuation in the thesis of LT Bankston:

a. All stations analyzed.

b. Isogradient assumption gave greater precision with fewer layers needed in the calculation.

c. Tracking programs not extremely sensitive to fine structure in the sound velocity profiles. Could use historical profiles.

d. Rise time of pulse seems to be a major source of uncertainty in the calculated vehicle position.

A theoretical analysis of the assumptions used in the tracking program has been started:

(1) Tilt calculation approximations. Contribution to final position error seems small.

(2) Accuracy of calculation of entry angle into the array.

a. Theoretical limits on the error here not yet quite satisfactorily established, although some insight has been gained.

b. Computational checks on program entry angle calculations for a target at known positions in isogradient water have been made. A crude range of error has been established.

(3) Limit of accuracy in overall position determination resulting from use of isovelocity programs applied to isogradient water.

(4) Position uncertainty resulting from smoothing SVP profile into one or only a few isogradient layers.

Immediate objectives for the coming year are:

(1) Completion of theoretical analysis above.

(2) Extension of the range experiment through use of BOMIS at the Nanoose range.

a. Check on the conclusions drawn from the Dabob Bay experiment.

b. Compare the calculated position coordinates obtained from different arrays observing the same target.

(3) Writing of a final report on the range experiments.

Publications:

1. M.S. Thesis: Ray Trace Experiment on the Underwater Range at Dabob Bay by Stuart C. Karon (December 1974; advisor: Sanders).

2. M.S. Thesis: An Analysis of a Ray Trace Experiment on the Underwater Range at Dabob Bay by Victor J. Bankston (March 1975; advisor: Sanders).

5. Range Concepts Task Group

Faculty: Wilson, Washburn

Student: LT Thomas

Efforts of this year have involved (a) a reexamination of arguments comparing the relative effectiveness of long base-line and short baseline systems of acoustic ranging and (b) some initial considerations for an on-board-torpedo navigation system.

(a) Range-only system.

We have referred to this system as the "cheap system". It is a spherical tracking system consisting of a fairly dense field of range-only sensors; it is contemplated that the inter-sensor spacing should be of the same order of magnitude as the depth of the water, and that accuracy will be obtained by making more range measurements than the minimal three. Preliminary computations assuming that ranging errors were independent and due to "jitter" in detecting the pulse arrival provided accuracies of the same order of magnitude as the wavelength at 75 kHz (about an inch). We are now proceeding under the assumption that ranging errors will not be limited by jitter in such a system, but rather by variations in the speed of sound along the several paths involved. This has been borne out in part by recent experiments at NTS. Since the ray paths lie in common water at the target end and in different waters at the sensor ends, it seems unlikely that accuracy can be computed using standard techniques and currently available measurements.

(b) On-board navigation. Some preliminary calculations have been made of the capability of a relatively inexpensive inertial navigation system which could be carried in the torpedo instrumentation section. A post-run analysis of data recorded by such a system could provide track information from torpedoes such as the Mk46 and Mk48 tested in the open sea without requiring a 3-D range. The preliminary conclusion reached was that the uncertainty in position after a thirty minute run caused by gyro precession and accelerometer drift was not competitive with that provided by the present ranging methods in use. However, the potential usefulness of such a system for a portable test range or for individual ship firings in open seas is so great that examination of this approach is presently being carried out as part of a student project. The technology for small inertial navigation systems is being assessed more carefully and more thoroughly.

Working documents, (Internal Distribution)

Working paper No. 29 A. R. Washburn: Insensitivity of Accuracy to Sensor Distribution. (Fall 74)

Working paper No. 30 A. R. Washburn: New Concepts: A cheap System (Fall 74)

6. Non-Acoustic Sensors Task Group

Faculty: Sackman, Menneken, Cunningham, Hoisington

A. Sub-Group Responsibility

1. The primary charge to this sub-group was to attempt to extrapolate from technical developments in the magnetic, electric and electromagnetic areas to possible weapon systems utilizing these signatures and the potential impact that these in turn might have on the demands for services placed upon a range station such as the Naval Torpedo Station by the Trident and SSBN programs.

2. An extension of this charge was to consider the implications of the establishment of the Trident facility on the Hood Canal on possible non-acoustic services which the Naval Torpedo Station range facilities might be called upon to provide for Trident. Since the Trident facility presently is modifying its plans for services required of NTS, this group will limit their efforts to making contact with that facility and monitoring their progress in coordination with the NTS-Trident coordinators.

3. A secondary charge to this sub-group was to determine to what extent, if any, non-acoustic communication or signaling could be used in the range operations, e.g., miss distance determination. No effort is being directed in this area due to a shift of priority to other tasks.

B. Approach

1. The obvious initial effort was to attempt to determine the state-of-the-art in the technology in this area. In view of the relatively low anticipated application of this technology to ASW, little significant funding has been provided for this area over the past several decades. As a consequence, only limited and fragmented work has been supported. Many of the basic understandings are lacking. In the past few years, for a variety of reasons, interest and concern in this areas has developed. Several meetings have been held and a number of programs are being funded to significant amounts. Specific information is being gathered by the sub-group on these developments. A Navy-wide Non-Acoustic Technology Steering Group is being formed with the Magnetic/Electric area as the first identified for intensive study. The Range Studies Group of the Naval Postgraduate School will have a member on this Steering Group so that a clear channel for information flow will be present.

2. Three members of the Magnetic/Electric Sub-Group attended a meeting in San Diego in November, 1974, devoted to Magnetic Silencing. The program included a number of papers on Electric and Electromagnetic signatures and measurements, as well as steady DC and degaussing. A complete description

of the installation planned in the Hood Canal for the Trident degassing range and the deperming pier and facility was given.

C. Progress In FY 75

1. A catalog of sensors appropriate for the measurement of both steady and alternating magnetic and electric fields is being assembled. In view of the recent activity in this effort, a literature search must be supplemented by an active and significant attempt to contact current workers to determine present capability and the goals which might be achieved in the next few years.

2. Due to the loss of Professor Menneken, the remainder of the effort has been directed toward reestablishing contacts and consolidating information from documentation on hand.

D. Planned Effort For FY 76

1. In the interest of focusing activity on one aspect of non-acoustic sensors with immediate priority, it is proposed to restrict the attention of this group to magnetic anomaly detection for this fiscal year. The objective will be to formulate the characteristics of a magnetic testing range.

7. Information Transmission, Processing and Display Task Group

Faculty: Powers, Sackman, Bank

Students: LCDR L. N. Schofield

Aspects of real-time information display have occupied most of this subgroup's activities this year. A visit to the Barking Sands range (BARSTUR) and a briefing on the Air Combat Maneuvering Range in Yuma, Arizona were very useful background.

A working paper giving initial ideas on the concepts and facilities for a range officer's real-time display was included in the midyear report. A student effort which carries this work further has been submitted as a thesis:

LCDR L. N. Schofield, "Design approach for a computer graphics system applicable to torpedo tracking and evaluation," MS Thesis, Naval Postgraduate School, June 1975.

ABSTRACT:

"This paper presents a design approach and specific considerations for a dedicated, real time, interactive, computer graphics system to be used in the tracking and evaluation of torpedoes utilizing an input from a three-dimensional tracking range. The basic parameters for making output, software and hardware decisions are presented with alternative examples given in each area of the design process."

Copies of the thesis will be transmitted separately when published. The content of both the working paper and the thesis is somewhat generalized. It thus may be usefully applied either to present NTS ranges or to future range operations.

In the thesis, the assumed need was to provide the information required by a range operator in order to conduct a torpedo test run, (such as on the Mk46 or Mk48), collecting useful data while maintaining safety precautions. Display parameters for the information are discussed, and a design of a suitable display format is presented. Drawings, and photographs of simulations, are included. Computer software and hardware considerations necessary to support the display of this information, as well as the collection of data for post-run analysis, were ingredients in devising a block diagram for a baseline system.

Although the considerations in the work above extended to such topics as providing maintenance aids, hard copy and a video record for the ship's company, it is significant to note that no need was discovered for a large-screen display. Such a device may be desirable in the actual circumstances at NTS, but probably only upon consideration of requirements not included in the work above. For example, the availability of an impressive color display for range visitors or conference viewing may justify such a facility.

Another activity of the subgroup was informal discussion with NTS personnel concerning their attempt to procure display equipment for attachment to the present, old XDS computers.

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